09-20-01 JC20 Rec'd PCT/PTO SEP 19 2001

| FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE<br>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371 | | ATTORNEY'S DOCKET NUMBER<br>**56383/70301**<br>U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR<br>09/937107 |
|---|---|---|
| INTERNATIONAL APPLICATION NO.<br>**PCT/EP00/02349** | INTERNATIONAL FILING DATE<br>**March 16, 2000** | PRIORITY DATE CLAIMED<br>**March 19, 1999** |
| TITLE OF INVENTION<br>**DEVICE FOR PRODUCING MONOCRYSTALS** | | |
| APPLICANT(S) FOR DO/EO/US<br>**Klaus Sonnenberg et al.** | | |

OIPE JC134 SEP 19 2001 PATENT & TRADEMARK OFFICE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☒ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☒ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

**Items 13 to 20 below concern document(s) or information included:**

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

   **Title page of WIPO publication; Form PCT /IB/308, Fig. 1, English Translation of amendment to page 2 of the specification of PCT Application; PCT Request, Form PCT/RO/101**

JC03 Rec'd PCT/PTO 19 SEP 2001

| U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/937107 | INTERNATIONAL APPLICATION NO. PCT/EP00/02349 | ATTORNEY'S DOCKET NUMBER 56383/70301 |
|---|---|---|

24. The following fees are submitted:.

| | CALCULATIONS | PTO USE ONLY |
|---|---|---|
| **BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5)) :** | | |
| ☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ............ **$1000.00** | | |
| ☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ........ **$860.00** | | |
| ☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ............ **$710.00** | | |
| ☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ............ **$690.00** | | |
| ☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) .......... **$100.00** | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | **$860.00** | |
| Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). | **$0.00** | |

| CLAIMS | NUMBER FILED | NUMBER EXTRA | RATE | | |
|---|---|---|---|---|---|
| Total claims | 48 - 20 = | 28 | x $18.00 | **$504.00** | |
| Independent claims | 1 - 3 = | 0 | x $80.00 | **$0.00** | |
| Multiple Dependent Claims **(check if applicable).** | | | ☒ | **$270.00** | |
| **TOTAL OF ABOVE CALCULATIONS =** | | | | **$1,634.00** | |
| ☐ Applicant claims small entity status. (See 37 CFR 1.27). The fees indicated above are reduced by 1/2. | | | | **$0.00** | |
| **SUBTOTAL =** | | | | **$1,634.00** | |
| Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). + | | | | **$0.00** | |
| **TOTAL NATIONAL FEE =** | | | | **$1,634.00** | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐ | | | | **$0.00** | |
| **TOTAL FEES ENCLOSED =** | | | | **$1,634.00** | |
| | | | | **Amount to be: refunded** | $ |
| | | | | **charged** | $ |

a. ☒ A check in the amount of **$1,634.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______ in the amount of ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **04-1105** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:


**Dike, Bronstein, Roberts & Cushman,**
**IP Group of Edwards & Angell LLP**
**P.O. Box 9169**
**Boston, MA 02209**
**(617) 439-4444**
**(617) 439-4170 (FAX)**


SIGNATURE

**George W. Neuner**
NAME

**26,964**
REGISTRATION NUMBER

**September 19, 2001**
DATE

09/937107

JC03 Rec'd PCT/PTO 19 SEP 2001

Attorney Docket No.: 70301/56383

**IN THE UNITED STATES PATENT OFFICE**

APPLICANT: Klaus Sonnenberg et al..

Entry of U.S. National Stage of
International application PCT/EP00/02349

For: DEVICE FOR PRODUCING MONOCRYSTALS

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**CERTIFICATE OF EXPRESS MAILING**

I hereby certify that this correspondence is being deposited with the United States Postal Service as Express Mail (Label No. EL895418689 US) in an envelope addressed to Box: DO/EO/US, Commissioner for Patents, Washington, D.C. 20231 on Sept. 19, 2001.

By: Rita Johnson
Rita Johnson

.......................................................................................................................

Box: DO/EO/US
Commissioner for Patents
Washington, D.C. 20231

Sir:

**PRELIMINARY AMENDMENT**

Please amend the above application as follows.

In the Specification:

Please amend the English translation of "Amended specification page 2" as follows.

Page 2, paragraph 4: please rewrite as follows:

A device characterized by an insulating device being planned that is designed in such a way that a heat flow in a radial direction vertical to the rotation axis (M) of the furnace (1) can be restricted to a preset rate and whereby the insulating device (6) is

designed so that its insulating effect is reduced from the cover heater (3) to the floor heater (2) [in accordance with the characterization clause of Claim 1] is familiar from the Journal of Crystal Growth, NL, North-Holland Publishing Co. Amsterdam, Vol. 166, No. ¼, September 1, 1996, pages 566-571.

Page 2, paragraph 6: please rewrite as follows:

The task is solved by means of a device for producing a monocrystal by growing from a melt of raw materials of the monocrystal to be produced with a heating appliance (1) for generating a temperature gradient within the melt of raw material whereby the heating appliance (1) has a rotationally symmetrical furnace (1) with a rotation axis (M)and with an essentially level floor heater (2) and an essentially level cover heater (3) that can be controlled to different temperatures and characterized by an insulating device being planned that is designed in such a way that a heat flow in a radial direction vertical to the rotation axis (M) of the furnace (1) can be restricted to a preset rate and whereby the insulating device (6) is designed so that its insulating effect is reduced from the cover heater (3) to the floor heater (2) [in accordance with Claim 1].

Page 2, paragraph 7: please rewrite as follows:

[Further developments are indicated in the subordinate claims.] In certain preferred embodiments of the invention, the device has a furnace designed cylindrically and a controller that is designed in such a way that the temperature of the floor heater (2) can be reduced in comparison with the temperature of the cover heater. In other preferred embodiments, the device has an insulator device (6) that is designed as a

tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom and placed in the furnace (1) in such a way that the tapered end is towards the floor heater (2). Preferably, the insulator device is made, for example, of graphite. In other preferred embodiments, the device comprises a furnace (1) having a jacket heater (5). In still other preferred embodiments, the device comprises a heat transmission part (6) having a rotationally symmetrical profiled or unprofiled shape. In yet other preferred embodiments, the device includes a heating surface of the heaters being calculated in a ratio to the diameter of the monocrystal to be produced so that a temperature that is essentially homogeneous over the radial cross-section surface of the monocrystal to be produced can be generated together with a temperature gradient between the first heater (2) and the second heater (3) that is essentially homogeneous and constant. Preferably, the size of the surface of each heater (2, 3) is at least 1.5 times the cross-sectional area of the monocrystal to be produced is calculated. Preferably, the controller is designed so that the temperature of the first level heater (2) can be lowered continuously as against the second level heater (3). In still other preferred embodiments, the clearance between the heaters is greater than the length of the monocrystal to be produced. In yet further preferred embodiments, a crucible (4) for receiving a melt of raw material of the monocrystal to be produced is provided between the first heater (2) and the second heater (3). Preferred devices of the present invention are particularly suited for the production of a monocrystal from a III-V composite semiconductor, for example, a monocrystal of gallium arsenide.

In the Claims:

Please cancel the amended claims 1-13 of the International application (PCT) and substitute the following new claims.

14. A device for producing a monocrystal by growing the monocrystal from a melt of raw materials with a heating appliance for generating a temperature gradient within the melt of raw material, wherein the heating appliance comprises a rotationally symmetrical furnace with a rotation axis (M) and with an essentially level floor heater and an essentially level cover heater that can be controlled to different temperatures, the device further comprising:

a first insulating device that is structured and arranged in such a way that a heat flow in a radial direction perpendicular to the rotation axis (M) of the furnace can be controlled at a preset rate; and

a second insulating device that is structured and arranged to provide an insulating effect having a gradient from the cover heater to the floor heater.

15. A device in accord with Claim 14, wherein the furnace is cylindrical and further comprising a controller to control a temperature of the floor heater to be lower than a temperature of the cover heater.

16. A device in accord with Claim 14, further comprising an insulator device having a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom, the insulator device being positioned in the furnace so that the tapered end is towards the floor heater.

17. A device in accord with Claim 14, further comprising a jacket heater for the furnace.

18. A device in accord with Claim 14, further comprising a heat transmission part having a rotationally symmetrical profiled or unprofiled shape.

19. A device in accord with Claim 14, wherein the heaters comprise a heating surface having a ratio to a surface of a monocrystal to be produced to provide a temperature that is essentially homogeneous over a radial cross-section of the monocrystal and a temperature gradient between the floor heater and the cover heater that is essentially constant.

20. A device in accord with Claim 19, wherein the surface of each heater is at least 1.5 times the cross-sectional area of the monocrystal.

21. A device in accord with Claim 15, wherein the controller can lower the temperature of the floor heater continuously with reference to the cover heater.

22. A device in accord with Claim 14, the device further comprising a clearance between the floor heater and the cover heater, the clearance being greater than the length of a monocrystal to be produced.

23. A device in accord with Claim 14, wherein said first insulator device comprises graphite.

24. A device in accord with Claim 14, further comprising a crucible for receiving the melt of raw material, the crucible being located between the floor heater and the cover heater.

25. A device in accord with Claim 14, wherein the furnace is cylindrical and further comprising:

a controller to control a temperature of the floor heater to be lower than a temperature of the cover heater;

an insulator device having a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom, the insulator device being positioned in the furnace so that the tapered end is towards the floor heater;

a jacket heater for the furnace;

a crucible for receiving the melt of raw material, the crucible being located between the floor heater and the cover heater; and

a clearance between the floor heater and the cover heater, the clearance being greater than the length of a monocrystal to be produced.

26. A device in accord with Claim 25, further comprising a heat transmission part having a rotationally symmetrical profiled or unprofiled shape.

27. A device in accord with Claim 25, wherein the floor and cover heaters comprise a heating surface having a ratio to a surface of a monocrystal to be produced to provide a temperature that is essentially homogeneous over a radial cross-section of the monocrystal and a temperature gradient between the floor heater and the cover heater that is essentially constant.

28. A device in accord with Claim 27, wherein the surface of each of the floor and cover heaters is at least 1.5 times the cross-sectional area of the monocrystal.

29. A device in accord with Claim 25, wherein the controller can lower the temperature of the floor heater continuously with reference to the cover heater.

30. A device in accord with Claim 25, wherein said first insulator device comprises graphite.

31. A method for producing a monocrystal of a III-V composite semiconductor material, said method comprising growing the monocrystal in a device according to any one of Claims 14 to 30.

32. A method for producing a monocrystal of gallium arsenide, said method comprising growing the monocrystal in a device according to any one of Claims 14 to 30.

## REMARKS

An early examination and notice of allowance are earnestly solicited.

Respectfully submitted,

Date: 18 Sept '01

By: George W. Neuner

George W. Neuner
Reg. No. 26,964

Dike, Bronstein, Roberts & Cushman
Intellectual Property Practice Group
EDWARDS & ANGELL, LLP
P.O. Box 9169
Boston, MA 02209
(617) 439-4444

**Appendix showing details of the amendment**

In the Specification:

Please amend the English translation of "Amended specification page 2" as follows.

Page 2, paragraph 4: please rewrite as follows:

A device characterized by an insulating device being planned that is designed in such a way that a heat flow in a radial direction vertical to the rotation axis (M) of the furnace (1) can be restricted to a preset rate and whereby the insulating device (6) is designed so that its insulating effect is reduced from the cover heater (3) to the floor heater (2) ~~[in accordance with the characterization clause of Claim 1]~~ is familiar from the Journal of Crystal Growth, NL, North-Holland Publishing Co. Amsterdam, Vol. 166, No. ¼, September 1, 1996, pages 566-571.

Page 2, paragraph 6: please rewrite as follows:

The task is solved by means of a device for producing a monocrystal by growing from a melt of raw materials of the monocrystal to be produced with a heating appliance (1) for generating a temperature gradient within the melt of raw material whereby the heating appliance (1) has a rotationally symmetrical furnace (1) with a rotation axis (M)and with an essentially level floor heater (2) and an essentially level cover heater (3) that can be controlled to different temperatures and characterized by an insulating device being planned that is designed in such a way that a heat flow in a radial direction vertical to the rotation axis (M) of the furnace (1) can be restricted to a preset

rate and whereby the insulating device (6) is designed so that its insulating effect is reduced from the cover heater (3) to the floor heater (2) ~~[in accordance with Claim 1]~~.

Page 2, paragraph 7: please rewrite as follows:

~~[Further developments are indicated in the subordinate claims.]~~ In certain preferred embodiments of the invention, the device has a furnace designed cylindrically and a controller that is designed in such a way that the temperature of the floor heater (2) can be reduced in comparison with the temperature of the cover heater. In other preferred embodiments, the device has an insulator device (6) that is designed as a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom and placed in the furnace (1) in such a way that the tapered end is towards the floor heater (2). Preferably, the insulator device is made, for example, of graphite. In other preferred embodiments, the device comprises a furnace (1) having a jacket heater (5). In still other preferred embodiments, the device comprises a heat transmission part (6) having a rotationally symmetrical profiled or unprofiled shape. In yet other preferred embodiments, the device includes a heating surface of the heaters being calculated in a ratio to the diameter of the monocrystal to be produced so that a temperature that is essentially homogeneous over the radial cross-section surface of the monocrystal to be produced can be generated together with a temperature gradient between the first heater (2) and the second heater (3) that is essentially homogeneous and constant. Preferably, the size of the surface of each heater (2, 3) is at least 1.5 times the cross-sectional area of the monocrystal to be produced is calculated. Preferably, the controller is designed so that the temperature

of the first level heater (2) can be lowered continuously as against the second level heater (3). In still other preferred embodiments, the clearance between the heaters is greater than the length of the monocrystal to be produced. In yet further preferred embodiments, a crucible (4) for receiving a melt of raw material of the monocrystal to be produced is provided between the first heater (2) and the second heater (3). Preferred devices of the present invention are particularly suited for the production of a monocrystal from a III-V composite semiconductor, for example, a monocrystal of gallium arsenide.

In the Claims:

Please cancel the amended claims 1-13 of the International application (PCT) and substitute the following new claims.

~~1. Device for producing a monocrystal by growing from a melt of raw materials of the monocrystal to be produced with a heating appliance (1) for generating a temperature gradient within the melt of raw material whereby the heating appliance (1) has a rotationally symmetrical furnace (1) with a rotation axis (M) and with an essentially level floor heater (2) and an essentially level cover heater (3) that can be controlled to different temperatures and characterized by an insulating device being planned that is designed in such a way that a heat flow in a radial direction vertical to the rotation axis (M) of the furnace (1) can be restricted to a preset rate and whereby the insulating device (6) is designed so that its insulating effect is reduced from the cover heater (3) to the floor heater (2).~~

~~2. Device in accordance with Claim 1, characterized by the furnace being designed cylindrically and by there being a controller that is designed in such a way that the temperature of the floor heater (2) can be reduced in comparison with the temperature of the cover heater.~~

~~3. Device in accordance with Claim 1, or 2 characterized by an insulator device (6) that is designed as a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom and placed in the furnace (1) in such a way that the tapered end is towards the floor heater (2).~~

~~4. Device in accordance with one of the Claims 1 to 3 characterized by the furnace (1) having a jacket heater (5).~~

~~5. Device in accordance with one of the Claims 1 to 4 characterized by the heat transmission part (6) having a rotationally symmetrical profiled or unprofiled shape.~~

~~6. Device in accordance with one of the Claims 1 to 5 characterized by a heating surface of the heaters being calculated in a ratio to the diameter of the monocrystal to be produced so that a temperature that is essentially homogeneous over the radial cross-section surface of the monocrystal to be produced can be generated together with a temperature gradient between the first heater (2) and the second heater (3) that is essentially homogeneous and constant.~~

~~7. A device in accordance with Claim 6, characterized by the size of the surface of each heater (2, 3) being at least 1.5 times the cross-sectional area of the monocrystal to be produced is calculated.~~

~~8. A device in accordance with one of the Claims 2 to 7 characterized by the controller being designed so that the temperature of the first level heater (2) can be lowered continuously as against the second level heater (3).~~

~~9. A device in accordance with one of Claims 1 to 8 characterized by the clearance between the heaters being greater than the length of the monocrystal to be produced.~~

~~10. A device in accordance with Claims 1 to 9 characterized by the insulator device being made, for example, of graphite.~~

~~11. A device in accordance with one of the Claims 1 to 10 characterized by a crucible (4) for receiving a melt of raw material of the monocrystal to be produced being provided that is located between the first heater (2) and the second heater (3).~~

~~12. A device in accordance with one of the Claimd 1 to 11 characterized by the device being a device for producing a monocrystal from a III-V composite semiconductor.~~

~~13. A device in accordance with one of the Claims 1 to 12 characterized by the device being a device for producing a monocrystal from gallium arsenide.~~

14. A device for producing a monocrystal by growing the monocrystal from a melt of raw materials with a heating appliance for generating a temperature gradient within the melt of raw material, wherein the heating appliance comprises a rotationally symmetrical furnace with a rotation axis (M) and with an essentially level floor heater and an essentially level cover heater that can be controlled to different temperatures, the device further comprising:

a first insulating devicc that is structured and arranged in such a way that a heat flow in a radial direction perpendicular to the rotation axis (M) of the furnace can be controlled at a preset rate; and

a second insulating device that is structured and arranged to provide an insulating effect having a gradient from the cover heater to the floor heater.

15. A device in accord with Claim 14, wherein the furnace is cylindrical and further comprising a controller to control a temperature of the floor heater to be lower than a temperature of the cover heater.

16. A device in accord with Claim 14, further comprising an insulator device having a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom, the insulator device being positioned in the furnace so that the tapered end is towards the floor heater.

17. A device in accord with Claim 14, further comprising a jacket heater for the furnace.

18. A device in accord with Claim 14, further comprising a heat transmission part having a rotationally symmetrical profiled or unprofiled shape.

19. A device in accord with Claim 14, wherein the heaters comprise a heating surface having a ratio to a surface of a monocrystal to be produced to provide a

temperature that is essentially homogeneous over a radial cross-section of the monocrystal and a temperature gradient between the floor heater and the cover heater that is essentially constant.

20. A device in accord with Claim 19, wherein the surface of each heater is at least 1.5 times the cross-sectional area of the monocrystal.

21. A device in accord with Claim 15, wherein the controller can lower the temperature of the floor heater continuously with reference to the cover heater.

22. A device in accord with Claim 14, the device further comprising a clearance between the floor heater and the cover heater, the clearance being greater than the length of a monocrystal to be produced.

23. A device in accord with Claim 14, wherein said first insulator device comprises graphite.

24. A device in accord with Claim 14, further comprising a crucible for receiving the melt of raw material, the crucible being located between the floor heater and the cover heater.

25. A device in accord with Claim 14, wherein the furnace is cylindrical and further comprising:

a controller to control a temperature of the floor heater to be lower than a temperature of the cover heater;

an insulator device having a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom, the insulator device being positioned in the furnace so that the tapered end is towards the floor heater;

a jacket heater for the furnace;

a crucible for receiving the melt of raw material, the crucible being located between the floor heater and the cover heater; and

a clearance between the floor heater and the cover heater, the clearance being greater than the length of a monocrystal to be produced.

26. A device in accord with Claim 25, further comprising a heat transmission part having a rotationally symmetrical profiled or unprofiled shape.

27. A device in accord with Claim 25, wherein the floor and cover heaters comprise a heating surface having a ratio to a surface of a monocrystal to be produced to provide a temperature that is essentially homogeneous over a radial cross-section of the monocrystal and a temperature gradient between the floor heater and the cover heater that is essentially constant.

28. A device in accord with Claim 27, wherein the surface of each of the floor and cover heaters is at least 1.5 times the cross-sectional area of the monocrystal.

29. A device in accord with Claim 25, wherein the controller can lower the temperature of the floor heater continuously with reference to the cover heater.

30. A device in accord with Claim 25, wherein said first insulator device comprises graphite.

31. A method for producing a monocrystal of a III-V composite semiconductor material, said method comprising growing the monocrystal in a device according to any one of Claims 14 to 30.

32. A method for producing a monocrystal of gallium arsenide, said method comprising growing the monocrystal in a device according to any one of Claims 14 to 30.

 1/PRTS



# Device for producing monocrystals

The invention concerns a device for producing monocrystals. In particular the invention concerns a device for producing monocrystals of various materials, for example III-V materials, for example of gallium arsenide monocrystals.

Familiar devices for producing monocrystals of various materials, for example III-V materials, for example of gallium arsenide monocrystals, generally comprise multiple temperature zone furnaces, such as those described in DE-OS-38 39 97 and in US patents US 4,086,424, US 4,423,516 and US 4,518,351.

These multiple temperature zone furnaces can consist not only of metal heat conductors but also of heating conductors containing carbon The so-called multiple zone tube furnaces enable a variable structure of a temperature field suitable for crystal growth and its displacement along the furnace's axis of rotation.

However, devices of this kind are characterized not only by an axial but also by a radial heat flow that can lead to a variable growth rate and to an unfavorable formation of the interphase melt-crystal.

In addition, multizone or multiple temperature zone furnaces are composed of a variety of thermal construction elements and this requires considerable expense for dismantling and assembling for maintenance work. As the number of zones increases the amount of automation increases and with it the susceptibility to faults of multizone furnaces.

In particular for the production of monocrystals with a large diameter, for example 2", 3", 100 mm, 125 mm, 150 mm 200 mm and above, there is the problem that a radial heat flow in the crystal has an effect on the isotherms, i.e. on the interphase melt-monocrystal in a vertical or axial direction respectively.

A device in accordance with the characterizing clause of Claim 1 is familiar from the Journal of Crystal Growth, NL, North-Holland Publishing Co. Amsterdam, Vol. 166, No. ¼, September 1, 1996, pages 566-571.

The task of the invention is to provide a device for producing monocrystals, in particular monocrystals of various III-V materials, for example from gallium arsenide, in which the heat control is almost exclusively axial.

The task is solved by means of a device in accordance with Claim 1.

Further developments are indicated in the subordinate claims.

The device has the advantage that a homogeneous axial heat flow is guaranteed and that practically no heat at all can run off in a radial direction, i.e. of a radially homogene-

ous temperature at the upper and lower heating plates and the intermediate sections.

Other elements and expediencies can be seen in the description of a design example by means of Fig. 1.

The figure shows a schematic cross-section view of the device according to the invention with an axis of rotation M extending vertically.

The device for producing monocrystals has a cylinder-shaped furnace 1 with a lower heating plate as the floor heater 2 and an upper heating plate as the cover heater 3. The high-temperature heat conducting plates (e.g. CFC) have a circular cross-section. The diameter of the floor heater 2 and of the cover heater 3 is not less than 1.5 to 2 times the diameter of the crystal to be produced, so that there are no radial heat flows in the system that are caused among other things through the non-rotationally symmetrical influences of the current supply. The clearance between floor heater 2 and cover heater 3 is dimensioned so that a crucible 4 for the crystal growth can be located between them.

A control appliance that is not shown is planned with which floor heater 2 and cover heater 3 can be triggered in such a way that cover heater 3 can be kept roughly at the melting temperature of the material to be processed and floor heater 2 can be kept at a slightly lower temperature. The controller is in addition designed so that the temperature of floor heater 2 can be continuously reduced in the growth process in comparison with the temperature of the cover heater, so that the melt of the raw material in the crucible 4 can harden continuously from bottom to top.

The cylindrical furnace 1 has in addition a jacket heater 5 that is formed for example in the cylindrical boundary wall of the furnace. There is a control appliance planned that

is designed so that the jacket heater 5 can be held at a temperature in the proximity of the melting point of the raw material in the crucible.

To prevent a flow of heat in a radial direction the furnace 1 has in addition a rotationally symmetrical insulator 6 made of heat-insulation material. Insulator 6 has the shape of a tapered body with a coaxial cylindrical interior that is open at the top and the bottom. The outer wall 7 of the insulator 6 is therefore shaped like a truncated cone and the inside wall 8 is shaped like a cylinder. Insulator 6 is arranged in the furnace in such a way that the tapered end 8 is in the direction of floor heater 2 and the end opposite to the tapered end is in the direction of cover heater 3. The inside diameter of the insulator is greater than the diameter of the crucible 4 that is to be inserted. The insulator is made preferably of graphite. The hollow truncated cone shape of the heat conducting profile 6 results in a free radiation space 9 between the heat conducting profile and the jacket heater 5 that contributes to the azimuthal compensation of the temperature through the main heater.

The design and arrangement of insulator 6 in the furnace 1 described above brings about a reduction in the heat insulation moving from the cover heater 3 to the floor heater 2 in a radial direction between a melt of raw material in crucible 4 and the jacket heater 5.

For operational purposes the crucible 4, which contains the crystal nucleus is placed into the furnace. Boroxide $B_2O_3$ and polycrystalline gallium arsenide are then added. The jacket heater 5 is then triggered in such a way that it is brought to a temperature that is sufficient to heat the reaction space to the working temperature and to melt the solid feedstock material. The added polycrystalline gallium

arsenide is melted so that it forms a gallium arsenide melt 10 and is covered by a covering melt 11 made of molten $B_2O_3$ so that contact of the gallium arsenide with the crucible wall is prevented.

The growing process is then carried out as follows. The cover heater 3 is brought to a temperature of approx. 1300°C and the floor heater 2 is brought to a temperature of approx. 1200°C. A temperature gradient is formed between the cover heater 3 and the floor heater 2 that is practically the temperature gradient that is found between two infinite parallel level plates. The temperature of the floor heater is then reduced continuously so that the melt 11 in the crucible 4 crystallizes out evenly from bottom to top. By controlling and/or regulating the temperature of the floor heater 2 relative to the temperature of the cover heater 3 it is possible to move the vertical position of the melt isotherms between the two heaters and therefore to control the crystallization. The jacket heater must be corrected slightly throughout the process time to maintain the ideal axial temperature, because the system's overall energy level is reduced, and to ensure that the radial losses, that are compensated for through the jacket heater, are reduced.

The jacket heater 5 serves to compensate global heat losses and to prevent a radial heat flow. Through insulator 6 a high level of insulation is achieved in the area of cover heater 3 in a radial direction and a lower level of insulation in the area of floor heater 2 in a radial direction. This guarantees an axial heat flow parallel to the rotation axis of the furnace during the crystallization process.

During the crystallization process and thereafter isotherm formation in the reaction vessel is in this way possible in any form. The isotherm form that is aimed for can be dis-

placed through the strictly axial heat flow over the complete height of the reaction space between cover heater 3 and floor heater 2.

The device in accordance with the invention enables the production of monocrystals of different III-V materials with large diameters, such as for example gallium arsenide with a diameter of 2", 3", 100 mm, 125 mm, 150 mm 200 mm and larger.

Depending on the monocrystal that is to be produced, for example in regard of its material or its diameter, the insulator 6 may be designed as a hollow cylinder. The aim is simply to guarantee a strictly axial heat flow and to prevent the heat flowing off in a radial direction. In this way the target can be reached of obtaining a constant rate of crystal growth per time unit.

In a modified form the heat transmission cylinder 6 is not in the shape of a tapered cone but is shaped so that a desired axial isotherm course is achieved. Any particular form is conceivable here and is calculated by means of the desired isotherm course. Any type of desired heat flow can be designed through the form of the material and the type of the material. In this way the target can be reached of obtaining a constant rate of crystal growth per time unit.

Amended claims for the national phases

1. Device for producing a monocrystal by growing from a melt of raw material of the monocrystal to be produced with a heating appliance (1) for generating a temperature gradient within the melt of raw material whereby the heating appliance (1) has a rotationally symmetrical furnace (1) with a rotation axis (M)and with an essentially level floor heater (2) and an essentially level cover heater (3) that can be controlled to different temperatures and characterized by an insulating device being planned that is designed in such a way that that a heat flow in a radial direction vertical to the rotation axis (M) of the furnace (1) can be restricted to a preset rate and whereby the insulating device (6) is designed so that its insulating effect is reduced from the cover heater (3) to the floor heater (2).

2. Device in accordance with Claim 1 characterized by the furnace being designed cylindrically and by there being a controller that is designed in such a way that the temperature of the floor heater (2) can be reduced in comparison with the temperature of the cover heater.

3. Device in accordance with Claims 1 or 2 characterized by an insulator device (6) that is designed as a tapered cone body with a coaxial cylindrical hollow space that is open at the top and bottom and placed in the furnace (1) in such a way that the tapered end is towards the floor heater (2).

4. Device in accordance with one of the Claims 1 to 3 characterized by the furnace (1) having a jacket heater (5).

5. Device in accordance with one of the Claims 1 to 4 characterized by the heat transmission part (6) having a rotationally symmetrical profiled or unprofiled shape.

6. Device in accordance with one of the Claims 1 to 5 characterized by a heating surface of the heaters being calculated in a ratio to the diameter of the monocrystal to be produced so that a temperature that is essentially homogeneous over the radial cross-section surface of the monocrystal to be produced can be generated together with a temperature gradient between the first heater (2) and the second heater (3) that is essentially homogeneous and constant.

7. A device in accordance with Claim 6 characterized by the size of the surface of each heater (2, 3) being at least 1.5 times the cross-sectional area of the monocrystal to be produced is calculated.

8. A device in accordance with one of the Claims 2 to 7 characterized by the controller being designed so that the temperature of the first level heater (2) can be lowered continuously as against the second level heater (3).

9. A device in accordance with one of the Claims 1 to 8 characterized by the clearance between the heaters being greater than the length of the monocrystal to be produced.

10. A device in accordance with Claims 1 to 9 characterized by the insulator device being made, for example, of graphite.

11. A device in accordance with one of the Claims 1 to 10 characterized by a crucible (4) for receiving a melt of raw material of the monocrystal to be produced being provided that is located between the first heater (2) and the second heater (3).

12. A device in accordance with one of the Claims 1 to 11 characterized by the device being a device for producing a monocrystal from a III-V composite semiconductor.

13. A device in accordance with one of the Claims 1 to 12 characterized by the device being a device for producing a monocrystal from gallium arsenide.

DIKE, BRONSTEIN, ROBERTS & CUSHMAN
INTELLECTUAL PROPERTY GROUP OF
EDWARDS & ANGELL, LLP
130 Water Street
Boston, Massachusetts 02109

HF 23-15431.Y



## DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed at 201) below or an original, first and joint inventor (if plural names are listed at 201-206 below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: DEVICE FOR PRODUCING MONOCRYSTALS

which is described and claimed in:

☒ the specification attached hereto.

☐ the specification in U.S. Application Serial Number ______________, filed on ________________.

☐ the specification in PCT international application Number, filed on ______________________; and was amended on __________________.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a). I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

**Prior Foreign/PCT Applications and Any Priority Claims Under 35 U.S.C. §119:**

| Application No. | Filing Date | Country | Priority Claimed Under 35 U.S.C. §119? |
|---|---|---|---|
| 199 12 484.1 | 19 March 1999 | Germany | ☒YES XXXXXX |
| | | | ☐YES ☐NO |
| | | | ☐YES ☐NO |

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below, and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose material information as defined in 37 CFR §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

Express Mail No. EL895418689US

| Prior U.S. Applications or PCT International Applications Designating the U.S-Benefit Under 35 U.S.C. §120 | | | | | |
|---|---|---|---|---|---|
| **U.S. Applications** | | | **Status (Check One)** | | |
| **Application Serial No.** | | **U.S. Filing Date** | **Patented** | **Pending** | **Abandoned** |
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| **PCT Applications Designating the U.S.** | | | | | |
| **Application No.** | **Filing Date** | **U.S. Serial No. Assigned** | | | |
| PCT/EP00/02349 | 16 March 2000 | | | | |
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## CLAIM FOR BENEFIT OF PRIOR U.S. PROVISIONAL APPLICATION(S) (35 U.S.C. §119(e))

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below:

| Applicant | Provisional Application Number | Filing Date |
|---|---|---|
| | | |
| | | |
| | | |

**POWER OF ATTORNEY**: As a named inventor, I hereby appoint the following attorney(s) with full powers of association, substitution and revocation to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

| | |
|---|---|
| Sewall P. Bronstein | (Reg. No. 16,919) |
| David G. Conlin | (Reg. No. 27,026) |
| George W. Neuner | (Reg. No. 26,964) |
| Linda M. Buckley | (Reg. No. 31,003) |
| Peter F. Corless | (Reg. No. 33,860) |
| Peter J. Manus | (Reg. No. 26,766) |
| Cara Z. Lowen | (Reg. No. 38,227) |
| William J. Daley, Jr. | (Reg. No. 35,487) |
| Robert L. Buchanan | (Reg. No. 40,927) |
| Christine C. O'Day | (Reg. No. 38,256) |
| Lisa Hazzard Swiszcz | (Reg. No. 44,368) |
| David A. Tucker | (Reg. No. 27,840) |
| George W. Hartnell, III | (Reg. No. 42,639) |
| Jennifer Holmes | (Reg. No. P-46,778) |
| Kerri Pollard Schray | (Reg. No. P-47,066) |

| SEND CORRESPONDENCE TO: | DIRECT TELEPHONE CALLS TO: |
|---|---|
| George W. Neuner<br>Dike, Bronstein, ~~Roberts & Cushman~~<br>Intellectual Property Practice Group<br>Edwards & Angell, ~~LLP~~<br>~~130 Water~~ Street<br>Boston, Massachusetts ~~02109~~ | George W. Neuner<br>(617) 523-3400 |

| No. | | | | |
|---|---|---|---|---|
| 201 | FULL NAME OF INVENTOR | LAST NAME<br>SONNENBERG | FIRST NAME<br>KLAUS | MIDDLE NAME |
| | RESIDENCE & CITIZENSHIP | CITY<br>52382 Niederzier | STATE OR FOREIGN COUNTRY<br>Germany | COUNTRY OF CITIZENSHIP<br>Germany |
| | POST OFFICE ADDRESS | POST OFFICE ADDRESS<br>Taubenforst 3 | CITY<br>52382 Niederzier | STATE OR COUNTRY AND ZIP CODE<br>Germany/52382 |
| 202 | FULL NAME OF INVENTOR | LAST NAME<br>KÜSSEL | FIRST NAME<br>ECKHARD | MIDDLE NAME |
| | RESIDENCE & CITIZENSHIP | CITY<br>52353 Düren | STATE OR FOREIGN COUNTRY<br>Germany | COUNTRY OF CITIZENSHIP<br>Germany |
| | POST OFFICE ADDRESS | POST OFFICE ADDRESS<br>Fritz Pleystraße 28 | CITY<br>52353 Düren | STATE OR COUNTRY AND ZIP CODE<br>Germany/52353 |
| 203 | FULL NAME OF INVENTOR | LAST NAME<br>BÜNGER | FIRST NAME<br>THOMAS | MIDDLE NAME |
| | RESIDENCE & CITIZENSHIP | CITY<br>09131 Chemnitz | STATE OR FOREIGN COUNTRY<br>Germany | COUNTRY OF CITIZENSHIP<br>Germany |
| | POST OFFICE ADDRESS | POST OFFICE ADDRESS<br>Klopstockstraße 3 | CITY<br>09131 Chemnitz | STATE OR COUNTRY AND ZIP CODE<br>Germany/09131 |
| 204 | FULL NAME OF INVENTOR | LAST NAME<br>FLADE | FIRST NAME<br>TILO | MIDDLE NAME |
| | RESIDENCE & CITIZENSHIP | CITY<br>09599 Freiberg | STATE OR FOREIGN COUNTRY<br>Germany | COUNTRY OF CITIZENSHIP<br>Germany |
| | POST OFFICE ADDRESS | POST OFFICE ADDRESS<br>Dörnerzaunstraße 11 | CITY<br>09599 Freiberg | STATE OR COUNTRY AND ZIP CODE<br>Germany/09599 |
| 205 | FULL NAME OF INVENTOR | LAST NAME<br>WEINERT | FIRST NAME<br>BERNDT | MIDDLE NAME |
| | RESIDENCE & CITIZENSHIP | CITY<br>09599 Freiberg | STATE OR FOREIGN COUNTRY<br>Germany | COUNTRY OF CITIZENSHIP<br>Germany |
| | POST OFFICE ADDRESS | POST OFFICE ADDRESS<br>Turnerstraße 9 | CITY<br>09599 Freiberg | STATE OR COUNTRY AND ZIP CODE<br>Germany/09599 |
| 206 | FULL NAME OF INVENTOR | LAST NAME | FIRST NAME | MIDDLE NAME |
| | RESIDENCE & CITIZENSHIP | CITY | STATE OR FOREIGN COUNTRY | COUNTRY OF CITIZENSHIP |
| | POST OFFICE ADDRESS | POST OFFICE ADDRESS | CITY | STATE OR COUNTRY AND ZIP CODE |

I hereby further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

| | |
|---|---|
| Signature of Inventor **201** 4.9.01 | Signature of Inventor **202** 4.9.01 |
| Date: | Date: |
| Signature of Inventor **203** | Signature of Inventor **204** |
| Date: 08/08/2001 | Date: 08/08/2001 |
| Signature of Inventor **205** | Signature of Inventor **206** |
| Date: 08/08/2001 | Date: |